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GEOMETRICAL ILLUSTRATIONS OF OHM'S LAW.*

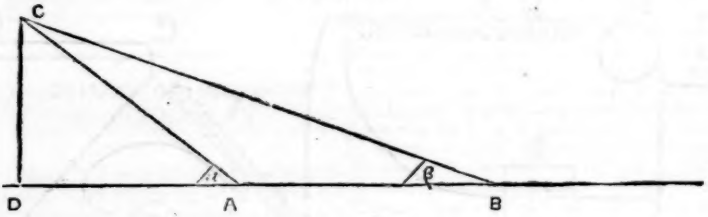
By Prof. G. C. FOSTER, F.R.S.

To find the *internal resistance* and the *electromotive force* of a battery without the use of tables.

I. By means of a *tangent galvanometer.*

A circuit is made up of a battery, tangent galvanometer, and set resistance coils. On making contact the galvanometer needle is deflected through an angle α; then a resistance R is added, and the deflection falls to the value . Take a point A in a straight line, and make angle $DAC = \alpha$. Make AB=R, and angle $DBC=\beta$. Let fall $CD + DB$.

FIG. 1.



Then DA measures original resistance of the circuit, and CD the electromotive force, because—

$$\frac{CD}{DA} = \tan\alpha = \text{1st current},$$

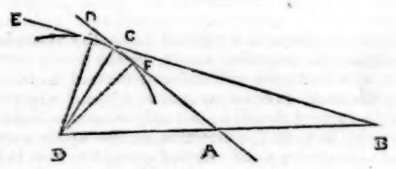
and—

$$\frac{CD}{DB} = \tan\beta = \text{2nd current}.$$

II. By means of a *sine galvanometer.*

Make $DAC = \alpha$, and $DBC = \beta$. Produce BC to E, and draw ED bisecting ECA. With centre

FIG. 2.



D draw a circle to touch AC and CE. The radius of this circle measures the electromotive force, and AD, as before, measures the internal resistance. For—

$$DF = \text{radius of circle} = DF',$$

$$\frac{DF}{DA} = \sin\alpha \text{ and } \frac{DF'}{DB} = \sin\beta.$$

* This simple method of demonstrating Ohm's law to a class in a rapid, clear manner, was read by Prof. G. Cary Foster at the recent meeting of the British Association, and communicated to us by the Author.

ON THE

USE OF ELECTRO-MAGNETIC INDUCTION IN CABLE SIGNALLING.

By G. K. WINTER, F.R.A.S.
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IT will doubtless be remembered by most telegraph engineers that at the Brighton meeting of the British Association I brought forward a subject connected with signalling on submarine cables that I thought had not received the attention it deserved. This subject was the use of an induction coil at the receiving end of a cable, the current from the cable being made to pass through the primary wire, and the currents generated in the secondary wire being used for working the receiving instrument.

There was one point connected with my experiments, and passed over as a matter of course in my paper, which seems, nevertheless, to have been misunderstood. I refer to the fact that, having a primary wire adapted as to its length and resistance for making the most of the received current, you may fill up the space to be occupied by the secondary wire with wire of any diameter, so long as you use a galvanometer or other receiving instrument of an appropriate resistance; in other words, the secondary coil must be treated as a distinct rheomotor, and, therefore, according to a well-known law, the resistance of the galvanometer should be equal to that of the secondary coil.

The resistance of my primary wire was about 2500 units, and, as explained in my paper, the resistances of the secondary coil and the galvanometer were about 2·5 units each. It is manifest that signals even from a strong battery, if passed through, say, 20,000 units, would scarcely affect such a galvanometer; whereas, if the same signals were passed through the primary wire of the above-mentioned induction coil, this same galvanometer would be specially adapted to show the currents generated in the thick secondary wire. A galvanometer, however, of the same dimensions, wound with 2500 units of fine wire, would be far more strongly affected by the direct signals than the thick wire galvanometer would be, even when joined to the secondary wire of the induction coil.

The induction coil is not therefore able to increase the *obtainable* strength of signals, but, if wound as mine was, it is able to convert signals that require a high-resistance instrument to show them into others that are best shown by one with low resistance. There are some instruments that are essentially low-resistance instruments, and which cannot be modified in this respect as galvanometers can. Such instruments would, of course, be useless as direct receiving instruments from long circuits

but would be rendered available for this purpose by means of the induction coil, just as my galvanometer of 2¼ units resistance was in my experiments in April, 1872.

My chief object, however, in writing the present paper, is to make known an important improvement I have made in the use of the induction coil in cable signalling. The great disadvantage in the use of the induction coil is the so-called *magnetic retardation* experienced by the cable current in passing through the primary wire. This magnetic retardation is caused by self induction in the primary wire; any change in the current passing through the wire tends to produce a current in the opposite direction to such a change, and in this way rapid changes are, as it were, clogged, the effect being very similar to an increase in the length of the cable, so that magnetic retardation seems a very appropriate name for expressing the effect.

A pretty experiment, showing the effect of this retardation, may be made in the following way:—

Now replace the electro-magnet by resistance of the same amount as the wire of the electro-magnet, and the character of the signals is immediately changed. The retardation is considerably lessened, and the effect is similar to using a much shorter cable.

This magnetic retardation is the chief drawback to the use of the induction coil. I have, however, been able not only to eliminate it, but to cause the self-induced currents which are its cause to aid in the formation of signals.

The method is briefly as follows:—The primary and secondary wires of an induction coil form two alternate branches of a Wheatstone's bridge; say A and B, Fig. 2, are these branches. The other branches are simple resistance, which may be made to produce balance when a constant current is flowing. G is the galvanometer or other receiving instrument. The current entering at C divides between the resistance and the primary wire. The increase of the current through the primary wire,

Fig. 1.

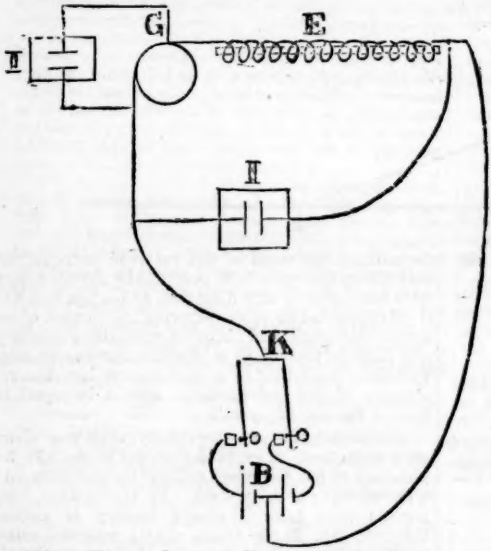
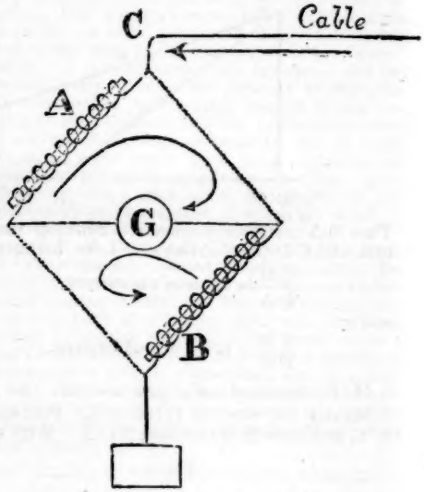


Fig. 2.



Let G, Fig. 1, be an ordinary mirror galvanometer, with a pretty thick fibre; E an electro-magnet, consisting of a large bar of iron, wound with, say, 2500 units of No. 30 silk-covered copper wire; I and I′ are induction batteries, consisting of lead plates in diluted sulphuric acid; K a key with two contact makers; and B a battery. If now the key is worked signals will be shown on the galvanometer closely resembling those received from a cable. This method of making a cheap artificial cable has been very useful to me in my experiments, and most probably may be useful to others. I may add that a simple reversal of these arrangements, placing the induction batteries in the main circuit, and the electro-magnet as the shunt, produces an effect analogous to what takes place at the sending end of a cable, and this constituted one of my first methods of forming a compensating circuit for applying duplex telegraphy to cables.

A, not only induces a current in B, the secondary wire, in the direction shown by the lower arrow, but also causes a self-induced current to flow in the direction of the upper arrow; again, the increase of the current through B not only causes an induced current in A, in the direction of the upper arrow, but also causes a self-induced current to flow in the direction of the lower arrow. During the decrease of the cable current the direction of the induced currents is reversed. It is this reversal of the induced currents during the decrease of the cable current which gives value to the induction coil in cable signalling. Now the self-induced currents, which in my plan aid the the formation of signals, are the very cause of magnetic retardation in the ordinary way of using the induction coil.

One great advantage in the use of the induction coil over the condenser plan, is the much greater safety the cable is placed in during the prevalence

of those intense earth currents which accompany magnetic storms. In my paper on earth currents I showed that the difference of potential between the conductor and the earth was the greatest possible when only one end of the cable was insulated, and least, or rather *nil*, when both ends were connected to earth. Now in the way in which cables are usually worked at present, the sending end of the cable is either connected direct to earth or through a small battery to earth, while the other end is insulated by the condenser. In this way the cable is, at the receiving end, submitted to the greatest strain possible. On some lines, however, the cable is kept completely insulated between two condensers, one at each end. It is not difficult to show that at each end of an insulated conductor the electrical strain (if we may so call it) between the conductor and the earth, produced by earth currents, would be just half that which would be produced at an insulated end when the other end is joined to earth. When using the induction coil, or my modification of it, as a receiving apparatus instead of the condenser, the cable is joined to earth at each end through a moderate resistance, and is therefore nearly in its safest possible state.

ON THE THEORY OF GRAMME'S MACHINE.

In a report made last year to the Paris *Société d'Encouragement*, when assigning to M. Gramme the prize for "a powerful and economical electrical apparatus," Count Du Moncel showed the importance of Gramme's machine in reference to industrial applications. In a recent number of the Society's *Bulletin* he considers the theory of the machine. We take the following instructive observations from his paper:—

From the scientific point of view the machine has a still higher value [than the industrial]; for it is based on a principle quite new, and seems to unite the two systems of induction, which, it is true, are indicated by theory, but which, up to the present, have engaged but little attention in their application to magneto-electric machines; I mean induction under the influence of magnetic effects produced in an iron core enveloped by an induced helix, and induction resulting from the movement of this helix before a magnetic system uniformly polarised; two sources which conspire in the same direction, and which may furnish a continuous current when the inducing action can be displaced in one direction in a continuous manner. We will endeavour to give some idea of this.

If we bring one of the poles of a permanent magnet, the north pole, *e.g.*, near one of the ends of a soft iron bar surrounded by a magnetising spiral, it will produce a current of magnetisation, the direction of which will vary according to the extremity of the bar acted on. This current is due to the transformation of the iron bar into a magnet. If we withdraw the magnet a current is produced, which is inverse to the former, and which corresponds to the demagnetisation of the bar. But if we bring the pole of the magnet towards the *middle* of the bar no current is produced, because the bar itself constitutes a magnet with consequent point, and the effect of induction produced to the right of this point is opposed by the effect produced to the left. Now, it results from this principle, that if the iron core with its surrounding helix be bent so as to form a ring, we shall be unable to obtain either currents of magnetisation or currents of demagnetisation through approach or withdrawal of the magnet, whatever point it may be directed to, for the parts to right and to left of the point influenced are then polarised in the same manner. If, however, we displace the magnet parallely to the axis of the bar, *i.e.*, circularly round the ring, the result will be different; a current will be produced which will neither be one of magnetisation nor of demagnetisation, but which will continue all the time that the magnet is in movement in the same direction, which may be an indefinite time by reason of the circular form of the bar. It will only change in direction when the movement is reversed. This current may arise, under certain conditions of winding of the helix, from two different and simultaneous actions, both of which, however, are caused by the successive displacement of the polarities developed at different points of the magnetic core of the ring under influence of the inducing magnet. One of these actions is the result of the magnetic perturbation determined in the ring itself by the successive interversion of polarities, a perturbation which may give rise, as I have proved, to a reaction similar to that observed when to an effect of demagnetisation is made to succeed one of magnetisation with opposite conditions; and since, under such conditions, the resultant currents have the same direction, and through the continuously advancing movement of the inductor, follow without interruption, we ultimately obtain a continuous current, which does not change in direction unless we change the direction of motion of the inducing pole. The other action arises from the movement of the inductor-magnetic system before the spirals of the induced helix, or (which comes to the same thing) the movement of these spirals before the inductor system.

When the annular helix is continuous and surrounds the magnetic ring throughout its extent, this latter action is of little energy; for, as we at once see, two contrary effects are produced; so that in this case the currents due to the first cause exist nearly alone; and, according to M. Gaugain's experiments, they are less energetic; but if the induced helix is divided into small portions separated from each other, and, while communicating together in tension (*i.e.*, so that the exterior end of the wire of one corresponds to the interior end of the wire of the next one), these portions are connected individually with a current collector by derivations forming contact with the collector at 90° from the inductor pole, the effects of which we spoke instead of being contrary will be superposed, and increase considerably the energy of the current already produced in the helix by interversion of the polarities of the ring; further, we may make opposite poles of the inductor-magnet act in a useful manner by arranging them at the two extremities of the same diameter of the annular magnet.

To understand this action, we have only to consider that an annular electro-magnet turning between the two magnetic poles of a horse-shoe magnet is

magnetised so that the system seems to be constituted by two semicircular magnets united to each other by their poles of the same name: whence it results that in the equatorial line, that is to say, in the diameter perpendicular to the line joining the two poles of the inductor-magnet, there are two neutral regions, and that the magnetising helix is dextrorsum for one of the sides of the ring and sinistrorsum for the other side. Now let us examine what happens when we cause helices of short length, like the portions of the helix in question, to move before such a magnetic system.

If we consider first the effect with reference to one only of the semicircular magnets, we may comprehend how the resultant of the actions of the turns of the magnetic helix corresponding to the neutral line of the magnet, that of the portions of induced helix which leave this line to go in the direction of the north inductor pole, *e.g.*, will produce, according to Lenz's law, a direct induced current. At the same time the portion of helix which follows on this resultant will produce an inverse induced current. It will be the same on the opposite side of the ring; but the magnetic resultant on this side being, with reference to the direction of winding of the bobbins, in the direction contrary to that just considered, the resulting currents will be found to be in a contrary direction to the former; that is, in such a way that the currents resulting from approach of the magnetic resultant of the left will be in the same direction as the currents resulting from withdrawal of the resultant of the right; and as this action is repeated for all the portions of the helix situated in each half of the ring, above and below the diameter corresponding to the two neutral lines, the result is that all the currents generated in each of the portions of the annular helix are in the same direction, but opposite among themselves from one portion to another. Nevertheless, as they are received after each passage of a portion before the two magnetic resultants by means of the corresponding derivations of the collector, they are, through this circumstance, in the case of two currents issuing from two equal piles arranged for quantity: that is, connected by their similar poles, and in place of annihilating each other they are superposed in quantity.

On the theory now expounded we have reasoned as if the annular helix were alone movable; but it is easy to understand that, though movable with this helix, the annular core presents always in reference to the collector and to the different parts of the apparatus polarities invariable in their position, and consequently the system of a turning iron ring is found to be in the same condition as a magnetic system formed of fixed permanent magnets; only with this arrangement we can add to the induced currents resulting from movement of the helix those resulting from interversion of the polarities, which renders this arrangement more advantageous than the other. We ought, however, to state that it is above all experiment and observation of the effects produced in machines of induction that have been M. Gramme's real guides in this discovery, and the theoretic question, as I have now set it forth, is the result of my own researches and those of M. Gaugain.

The author concludes his paper with a description of several different forms of the machine.

ELECTRO-DEPOSITION OF METALS.

By J. T. SPRAGUE.

(Continued from page 294.)

WHAT is the quantitative relation between electricity and matter indicated by the considerations examined on p. 293? Is it molecular or atomic? Is it dependent on the atomic weight of the modern chemical notation? or is it, as nine people out of ten suppose, dependent upon the old equivalent weights? Upon none of these, and yet upon all of them. Our knowledge is, in fact, not yet sufficiently advanced to enable us to give a definite explanation of the mode of relation between electricity and the molecular constitution of matter. In the Table (p. 136, col. VI.) is given a list of the actual quantitative relations; and a little examination of some of the relations of matter and energy may throw some new light both upon the cause of these relations and upon the chemical constitution of substances.

The elements combine with each other in exact definite ratios, and those ratios have a twofold aspect:—(1), the *weight* of matter involved; (2), the *measures* in the gaseous states. The atomic weights now adopted (given col. III. of Table, p. 136) combine both these aspects: they are the weights of those measures which equal in volume 1 weight of hydrogen. Some substances cannot be so measured, and the figure is arrived at indirectly; some, again, are experimentally exceptions: they may be half or double measures when actually compared as elements, and yet when entering compounds they agree with the accepted figures. This requires explanation; why is a law to be accepted as universal when experiment shows us there are exceptions? Experiment is the foundation of all knowledge, but the deductions from experiment must be broad; they must be based upon the *spirit*, not upon the *letter* of the replies which Nature gives to our questions. When several different experiments appear at first to differ in their teachings, it is our duty to see if we cannot find some broader road to knowledge of which there are several bye-ways. The relations of energy to matter vary in different physical states, and in the one physical state of gas they vary according as we recede from the point at which the gas becomes a liquid, that which is commonly called the boiling-point. Yet through all these variations we see a fundamental law of Nature (the law of Boyle and Mariotte, Dulong and Petit): the relation of energy to matter as gas is definite,—equal heats, equal pressures, produce equal expansion and contraction. The variations are due to the imperfect gaseous condition,—to our want of power to compare all bodies at the proper point at which Nature fixes that relation; therefore in our experiments we employ part of the energy we use in carrying out some other kind of relation as well as the particular one we wish to examine. The remedy is, to arrive, as far as possible, at the knowledge which each experiment gives in one direction, and then to accept the general teachings to be derived from many.

It is upon this principle that we may regard the accepted atomic weights as representing the abstract unit gas volumes of the several atoms, and two such unit *atomic* volumes as the unit *molecular* volume, into which Nature compresses all the atoms of which she builds up every molecule of known

substances. But these atoms do not combine in mere pairs. One volume or atom is *equivalent* to, or can combine with or replace, one, two, three, or more atoms or unit volumes of other elements; yet when so combined—no matter how many volumes enter into union—they condense down to *two* volumes. This is so universal that we are bound by the principles of honest reasoning to recognise that the apparent exceptions are due to the different conditions of energy to which we are compelled to expose, in order to compare, them. Taking, then, the unit volume of hydrogen, the lightest substance and the most perfect gas (therefore the simplest known substance in its relation to energy), as our base, we class atoms as equivalent to one, two, three, four, &c., atoms of hydrogen, and call this relation the valency of the atoms. Some substances are capable of possessing two or more valencies; thus copper, a bivalent atom, unites with chlorine, a univalent element, as $CuCl_2$; but it also unites with it as Cu_2Cl_2. We know that each atom is not mere matter,—energy is also part of its essence; the atom is a vibrating body, and the space it occupies—its unit volume—depends on this motion: we have, then, the right to conclude that copper can part with some of this intrinsic energy, that two ordinary atoms can condense into one, and will then represent matter and energy constituting one atom, occupying one abstract unit gas volume, and having—in its relations to other atoms and to energy—the value of one atom only, but capable of again absorbing energy, and so re-constituting two atoms.

Now Energy, in the form of Electricity, is related to the atoms and molecules in a manner which links together these other relations. This relation can be formulated as—

$$\frac{\text{Atomic weight}}{\text{Valency}} = \text{electric equivalent.}$$

We can therefore give to Faraday's "quantity," or "equivalent of electricity," a definite value accordant with the chemical constitution of matter: it is that action which will release one atom of a univalent substance, elementary or compound. Still more strictly, it will release one univalent *radical*, which radical may be a single atom, or may be built up of many atoms of any valency brought into that state which corresponds physically and in its relation to energy with the unit gas volume and single valency. This unit of electricity, measured on a grain system, is that used in these papers, the equivalent of 1 grain of hydrogen. Each molecule, therefore, acts in the electric circuit as though it were so many molecules as would represent the "valency" of the two radials or *ions* into which it breaks up. How or why this relation exists our present knowledge does not enable us to explain, but that this is the true relation of electricity to matter is certain, for this law covers all the known facts, all the exceptions to the common accepted laws of electrolysis (p. 293); but we can see that it is probably connected with the unit atomic gaseous relation of matter and energy, extended into all other physical conditions.

This is the relation of quantity or current intended to be conveyed by the *number* of the links between the two halves of the molecules in the figure (p. 136). There is another relation of *tension* represented by the *strength* of those links which corresponds to the truth which underlies Berzelius's electro-chemical theory (p. 293).

When two electrodes are immersed in a solution we may regard the action from two aspects:—(1). The solution may be considered as a *conductor*, having a specific resistance, passing current according to the well-known laws. (2). We may regard the solution as a *dielectric*, and the electrodes as condenser plates which we can charge up to a certain tension at which the dielectric breaks down. Each electrolyte, in fact, requires a specific tension exerted upon it before it permits current to pass: that tension is the same as the electromotive force the ions to be separated would set up in combining, and acts as an opposing electromotive force; so that the formula for the electromotive force necessary to effect any reaction at a given rate, that is to pass a given current through a given electrolyte, is—

$$\frac{E - e}{R} = C.$$

It is universally stated that electrolysis is of two orders:—(1). *Direct*, where one substance gives up its constituents as two ions, as, for instance, hydrochloric acid, breaking up into hydrogen and chlorine, $HCl = H + Cl$. (2). *Secondary*, where these ions do not themselves appear, but are supposed to react chemically upon some other substance present in the solution. To this action most of the reductions of electro-metallurgy are considered to be due: the current is supposed to be conveyed by the acid or by the water, and the "nascent" hydrogen is supposed to act upon the metallic salt and reduce the metal. Why this should be supposed it is difficult to see; but this explanation is commonly given and accepted. The various reactions which are called the "decomposition of water" are of the same order. Water is a non-conductor, and not an electrolyte, but is said to be rendered conducting by the presence of acids and salts: these are supposed to carry the current, and by a *secondary* reaction the released ions decompose water. Take sulphate of soda, Na_2SO_4, as an example: at the cathode sodium is set free, reacts on water chemically, $Na + H_2O = NaHO + H$, settting free hydrogen: at the anode, oxysulphion or sulphuric radical, SO_4, tends to becoming free, but, being unable to exist as a separate body, it also acts on water and $SO_4 + H_2O = H_2SO_4 + O$, giving up oxygen; at the same time acid is found at the anode, and caustic soda at the cathode. Probably the origin of this idea was the endeavour to fit facts to a preconceived theory of the equivalent action of electricity at a time when there was not sufficient knowledge attained.

To understand what really occurs, and so get rid of the complication of direct and secondary electrolysis, we must distinguish between the actions which occur at the *electrodes* and in the body of the *liquid*. In the latter the transmission of current is a pure matter of resistance; those molecules will transmit the current which most freely form the lines of polarisation, and either break up and re-form or revolve under the polar actions most easily. At the electrodes the several ions become free unless there is something they can combine with, and the process would appear to be this:—There is not direct electrolysis, as hitherto supposed, but at each electrode such radicals are either set free or formed out of the materials there present as can constitute free molecules with least expenditure of energy. In the decomposition of sulphate of soda there is no secondary or merely chemical

action, as usually supposed, but molecules of water enter the polar chain itself, and the extreme ions of the chain go off as gases.

$$+\overbrace{O^{H}_{H}}\ \overbrace{SO_4{}^{Na}_{Na}}\ \overbrace{SO_4{}^{Na}_{Na}}\ \overbrace{OHH}$$
$$\overbrace{\quad}\ \overbrace{\quad}\ \overbrace{\quad}\ \overbrace{\quad}$$

This reaction requires 1·5 equivolts of energy to effect,—that is, so much energy must be given up by the current, in order to set oxygen and hydrogen free, and the cell will act as a $-e$ of that force. But if the anode is made of copper, current would pass with less expenditure, and the action would become—

$$+Cu\ \overbrace{SO_4{}^{Na}_{Na}}\ \overbrace{SO_4{}^{Na}_{Na}}\ \overbrace{OHH}$$
$$\overbrace{\quad}\ \overbrace{\quad}\ \overbrace{\quad}$$
$$+1{\cdot}26 \qquad -1{\cdot}5$$

Here we see that the energy absorbed is 1·5 − 1·26, or only 0·24 of an equivolt (these figures are only approximate), because at the anode a reaction occurs which gives up energy, or, more simply, there is only absorption at the cathode for setting hydrogen free. But if we have, at the cathode also, an ion present which requires no more energy to set it free than a corresponding ion at the anode will supply, we have an electrolysis which is only a resistance, not a − electromotive force, and which therefore the very feeblest force can accomplish: we have then—

$$+Cu\ \overbrace{SO_4{}^{Na}_{Na}}\ \overbrace{SO_4{}^{Na}_{Na}}\ \overbrace{SO_4Cu}$$
$$\overbrace{\quad}\ \overbrace{\quad}\ \overbrace{\quad}$$
$$+1{\cdot}26 \qquad -1{\cdot}26$$

This is an ordinary coppering reaction, in which, to keep up the analogy, I have used the soda sulphate in the circuit, instead of copper sulphate or sulphuric acid as usual.

Therefore, in a mixture of electrolytes, or when there are several ions at an electrode, the current selects to set free, that which requires the lowest "intrinsic energy." Hence it is that if iron or zinc are present in a solution of copper sulphate, pure copper will be reduced, because its energy is 1·26 equivolts, while iron is 2·07.

But this holds true exactly only so long as the tension at the electrodes, regarded as condenser plates, is kept at about the proper point: if by increasing the electromotive force of the circuit, and by arrangement of resistances, we raise the tension, ions suited to that tension will come off: thus, if in a coppering cell we raise it over 0·24, there will be a tendency for hydrogen to come off with the copper, and the deposit will become friable, and even a brown powder—due to a true secondary action, as hydrogen—will really be set free, and react upon the solution.

Hence it is that in some cases, despite of Smee's laws, to get a deposit of metal at all we must also have gas going off. It is thus with iron whose energy is 2·07, while that of hydrogen (in sulphuric acid) is about 1·92. Here the hydrogen must come off with the iron, but it cannot react upon the iron solution, and the same is the case with nickel.

In electrolysis there is, therefore, no direct transfer of ions from one side to the other, but a constant interchange of radicals in contact, which owing to the selective power exerted at the electrodes tends to the accumulation of two classes of radicals, which in the case of a salt in solution would ultimately result in collecting all the acid on one side and all the base on the other; but this could never be effected as many suppose by a current equivalent only to these radicals; in practice, also, in an open depositing cell the result of long-sustained action is the transfer of the metal of the anode to the cathode. But the anions or chlorous radicals tend to accumulate most rapidly, and this has important results in electro-metallurgy, because these chlorous radicals act on the anode and surround it with a heavy saturated solution; while the removal of the metal at the cathode tends to produce a weak and acid solution there, just where a dense metallic solution is most desirable; in fact, if we use a neutral solution of copper sulphate in a cell with a porous partition, and drive a strong current through, in a little while the anode will be covered with crystals of sulphate of copper formed there, but unable to dissolve, while the solution at the cathode will be exhausted so as to give the metal only as a powder.

The mode of transmission of ions and the way in which the metal of the anode is transferred to the cathode may be represented in the following diagram, in which copper is supposed to be immersed in sulphuric acid:—

$$\overset{+}{\overbrace{\quad}}$$
1. $Cu\ \overbrace{SO_4H_2}\ \overbrace{SO_4H_2}\ \overbrace{SO_4H_2}$
2. $Cu\ SO_4Cu\ SO_4H_2\ SO_4H_2$
3. $Cu\ SO_4Cu\ SO_4Cu\ SO_4H_2$
4. $Cu\ \underbrace{SO_4Cu}\ \underbrace{SO_4Cu}\ \underbrace{SO_4Cu}$

The upper brackets show the constitution before action, and the lower ones the result of one action upon each molecular chain; after each action, which involves a re-distribution of the radicals, the newly-formed molecules make a semi-revolution so as to renew the polar condition; at each action, therefore, a molecule of copper sulphate is formed by copper entering at the + end, and hydrogen leaving at the cathode, until at length copper sulphate reaches the cathode, and copper can be set free there instead of hydrogen.

MATHEMATICS
FOR
NATURAL SCIENCE STUDENTS.

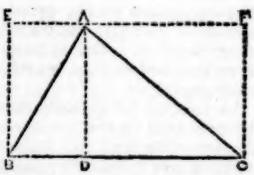
By T. C. SIMMONS, B.A.

Trigonometry (*concluded*).

To find the Area of a Triangle.—

Let A B C be a triangle. It is usual in trigonometry to denote the side B C by a, C A by b, and A B by c, so that each side is denoted by a letter

Fig. 34.



the same as that which is used for the opposite angle.

Draw A D perpendicular to B C, E A F parallel

to B C and again B E, C F parallel to A D, as indicated by the dotted lines. Then E D, D F, E B C F are rectangles, and it is not difficult to see that the triangle A B D is one-half of E D, and A C D one-half of D F; thus the whole triangle A B C is one-half of the whole figure E B C F.

But the area of this latter figure is equal to B C × E B. Thus the area of A B C is equal to ½ B C . E B, or to ½ B C . A D, A D being equal to B E.

If we call B C the *base* of the triangle, and A D, the perpendicular from A on B C, its *altitude*, we get—

The area of a triangle is half the product of the base and the altitude. And here I wish not to be misunderstood. By the product of the base and altitude I mean this—If the one be 3 inches and the other 2 inches, the product will be 6 square inches; if the one be 2 feet and the other 5 feet, the product will be 10 square feet; and so on.

Now $A D = A B \sin B$.

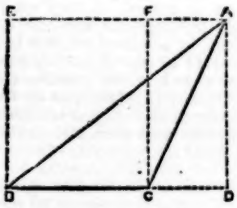
Hence area $= \frac{1}{2} B C . A B \sin B$,

$= \frac{1}{2} a c \sin B$.

In a similar way we might show that the area $= \frac{1}{2} a b \sin C$, or $\frac{1}{2} b c \sin A$.

If the perpendicular from A were not to fall between B and C it would fall on B C produced, either at a point beyond B or beyond C. In this case we should find the triangle A B C to be the *difference* between two other triangles, and E B C F the *difference* between two other rectangles, and we should still get the area $= \frac{1}{2} a c \sin B$. The adjoining figure will sufficiently explain what I mean:—

Fig. 35.



Thus the area of a triangle is equal to half the product of any two sides into the sine of the included angle.

On the Relation between any Side of a Triangle and the Sine of the Opposite Angle.—

If we refer to Fig. 34 we see that—

$$\frac{\text{Sin B}}{\text{Sin C}} = \frac{\frac{A D}{A B}}{\frac{A D}{A C}} = \frac{A D}{A B} \times \frac{A C}{A D} = \frac{A C}{A B} = \frac{b}{c},$$

and the same thing holds when A C B is greater than a right angle, as is seen in Fig. 35: the sine of A C B is positive, and is $\frac{A D}{A C}$ (see No. 33, p. 227).

This might be expressed differently; for since—

$$\frac{\text{Sin B}}{\text{Sin C}} = \frac{b}{c}$$

we get $c \sin B = b \sin C$, or, dividing both sides of the equation by $b c$,—

$$\frac{\text{Sin B}}{b} = \frac{\text{sin C}}{c}.$$

In the same way we might get—

$$\frac{\text{Sin A}}{a} = \frac{\text{sin C}}{c}.$$

Thus—

$$\frac{\text{Sin A}}{a} = \frac{\text{sin B}}{b} = \frac{\text{sin C}}{c},$$

or—*The sides of any triangle are proportional to the sines of the opposite angles.*

To express the Cosine of any Angle of a Triangle in terms of the Sides.—

If A B D be a right-angled triangle (Fig. 34), D being the right angle, we know that—

$$A B^2 = A D^2 + D B^2.$$

(Tel. Journ., No. 29, p. 167).

Now A C is greater than A D, and B C greater than B D; thus A B is less than $A C^2 + C B^2$. Thus in a triangle the square on the side opposite an acute angle is less than the sum of the squares on the sides containing that angle. It is proved by Euclid, in Book II., Prop. 13, that the difference between the two is twice the product of C B and C D.

Thus—

$$A B^2 + 2 C B . C D = A C^2 + C B^2,$$

or— $$2 C B . C D = A C^2 + C B^2 - A B^2,$$

or— $$2 C B . C A \cos C = A C^2 + C B^2 - A B^2,$$

or— $$2 a b \cos C = b^2 + a^2 - c^2.$$

Thus— $$\cos C = \frac{a^2 + b^2 - c^2}{2 a b}.$$

Again, in the case where C is greater than a right angle (Fig. 35) it is not difficult to see that $A B^2$ is greater than $A C^2 + C B^2$ (for $A D^2 + D B^2$, to which $A B^2$ is equal, is greater than $A C^2 + C B^2$).

In Euclid, Book II., Prop. 12, it is proved that $A B^2 = A C^2 + C B^2 + 2 C B . C D$.

Now $C D = C A \cos A C D$,

$= - C A \cos A C B$.

(Tel. Journ., No. 33, p. 228).

Thus—

$A B^2 = A C^2 + C B^2 - 2 C B . C A \cos A C B$,

or—

$2 C B . C A \cos A C B = A C^2 + C B^2 - A B^2$,

whence, as before, we get—

$$\text{Cos C} = \frac{a^2 + b^2 - c^2}{2 a b}.$$

In the same way we might show that—

$$\text{Cos A} = \frac{b^2 + c^2 - a^2}{2 b c},$$

or that—

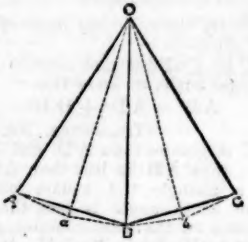
$$\text{Cos B} = \frac{a^2 + c^2 - b^2}{2 a c}.$$

To find the Area of a Circle.—

Let O be a point from which three straight lines —O A, O B, O C—are drawn, all equal to one another, the angles A O B, B O C being likewise equal. Join A B, B C. Then if h be the length of the perpendicular from O on A B or B C (these two perpendiculars are evidently equal), and l be the length of A B or B C, h is the altitude and l the base of each triangle. Hence the area of each is $\frac{1}{2} h l$, and the area of the two together is $2 . \frac{1}{2} h l$. Now let us bisect A O B, B O C by O a, O b, and let each of these lines be made equal to O A, O B, or O C. Then the area of the four triangles whose

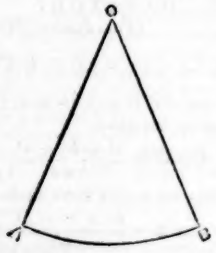
bases are A a, a B, B b, b C, will be, in a similar manner, 4 . ½ h' l', where h' is the altitude of any one of the new triangles and l' the length of any one of the bases. If we now bisect all these four angles, and draw triangles as before, we shall find the area of the eight new triangles to be 8 . ½ h'' l'', where h'' is the new altitude, l'' the length of any

FIG. 36.



one of the new bases. Putting this in the form ½ h'' . 8 l'' we see that it is half the product of the altitude and the sum of the bases. Now if we continue to subdivide in this manner, we shall always get the same result: the whole area will always be half the product of the altitude and the sum of the bases. But when the number of triangles is very much increased, so that they all are very narrow, we get a figure very nearly resembling a portion of a circle, of which O is the centre and the small bases the approximate circumference. We can, by making the number of triangles indefinitely large, and each of them indefinitely narrow, get a figure not distinguishable from a portion of a circle. And in this case the area will be equal to half the product of the altitude and the sum of the bases. Thus we see that the area of a circular

FIG. 37.



sector, such as O A B, must be half the product of the radius and the length of the arc A B.

If instead of a portion of a circle we take a whole one, the same result will follow, so that we get this result:—*The area of a circle is half the product of its radius and circumference.*

Now 2π is the ratio of the circumference of a circle to its radius, where π denotes 3½ nearly (see TEL. JOURN., No. 29, p. 164). Thus if r be the length of the radius, $2\pi r$ will be the length of the circumference, and we get the area—

$$= \tfrac{1}{2}\, r \,.\, 2\pi r = \pi r^2.$$

Thus, to find the area of a circle we must multiply r^2, which is the area of a square described on the radius, by 3.14159, which is the value of π to five places of decimals.

NOTES RELATING TO ELECTRIC FUZES.*

By F. A. ABEL, F.R.S., Treas. C.S.

THE earliest practical application of electricity to the explosion of submerged charges of gunpowder was made by Sir Charles Pasley, who, in the course of operations which he was carrying on for removing the wreck of the *Royal George* at Spithead, consulted the late Professor Daniell and Sir Charles Wheatstone, at King's College, on the subject, the result being the employment by him of a form of Daniell's Battery for the purpose of heating to redness a platinum wire surrounded by gunpowder.

In 1856 the subject of the application of electricity to the explosion of gunpowder was referred for experimental investigation to the Ordnance Select Committee, of which Colonel Bainbridge, R.E., Sir Charles Wheatstone, and I were then members. The investigations had reference to the further development of the application of high tension currents, as obtained with electro-magnetic induction coils and frictional machines (including Armstrong's hydro-electric machine), to the explosion of mines, and especially to the utilisation of magneto-electric induction apparatus in the same direction. The production of a highly sensitive and otherwise efficient fuze for employment with such instruments, as well as with other high tension apparatus, was made the subject of special investigation by me, in which I received most valuable assistance from Mr. E. O. Brown. After applying gun-cotton and various other highly sensitive compounds and preparations as priming (or vehicles for ignition) of such fuzes, the ultimate result was the production of the high tension phosphide of copper fuze, through the agency of which even small voltaic piles and so-called galvanic chains, as well as the simple forms of magneto-electric machines manufactured for medical purposes, became available for the explosion of mines. A very efficient magneto-electric exploding machine was also devised, by Sir C. Wheatstone, by means of which a large number of those fuzes could be exploded in divided circuit with such rapidity as to have the practical effect of simultaneous explosions in operations *on land*, and which served as the foundation for the construction of other instruments of the same class. Although the highly sensitive character of the phosphide of copper fuze has rendered it very valuable and superior to other fuzes of similar nature as a means of exploding mines and groups of mines, both land and submarine, its very sensitiveness became an obstacle to its employment with confidence in *submarine* mines. I was therefore recently led to devise a modification of the high tension fuze, specially designed for use in submarine mines, and which, while possessing the requisite sensitiveness to ignition, has been proved by ample experiments to sustain with absolute safety the transmission of any test-currents to which it may be necessary or desirable to submit them.

This fuze dispensed with the necessity for employing cumbrous and troublesome batteries, and rendered the success of exploding operations independent of distance and of good metallic connections. These high tension fuzes met with varying success. One chief objection arose from their deterioration whenever they became moist, and to which accident they were very liable. A very substantial objection to their use in submarine mines was, however, the liability to considerable alterations in conductivity by being frequently, or for long periods, submitted to even feeble test-currents, and the possibility of its accidental ignition by passing through them such comparatively powerful test- or signal-currents as it may be found necessary to

* Abstract of a Paper read before the Society of Telegraph Engineers.

employ in conjunction with an efficient system of submarine mines. The new tension fuze, specially devised by me for use in submarine mines, is, as already stated, quite free from the latter defect, and, though its conductivity is by no means unaffected by the long-continued transmission of test-currents through it, the changes to which it is liable in this respect have been found, so far as present experience goes, not to affect its efficiency. Owing to the great liability which high tension fuzes have of exploding accidentally from induced currents a lighting discharge will probably decide whether it is desirable to replace them with low tension or wire fuzes.

The highly permanent character of platinum, combined with the comparatively great resistance which it opposes to the passage of an electric current, has led to its being almost exclusively used until quite recently as the material for the construction of the bridge or the source of heat in low tension fuzes. The wire of this material hitherto used in the production of fuzes for military purposes has varied somewhat in diameter, and the resistance offered by it is not very high. Its average diameter is about 0·003", and its weight 1·65 grains per yard; its resistance is equal to about 31 ohms per yard, so that the length of the wire which has generally been introduced into the construction of a fuze has offered a resistance of about 0·2 ohm. Several very full experiments were made to ascertain how far the sensitiveness of low tension fuzes could be increased by employing thinner wires than 0·003" inch, and it was found that the conductivity of such *fine* platinum wires as are employed in the construction of electric fuzes is but slightly affected by physical differences in the metal from which they are produced, and that the considerable variations observed in the electric resistances of commercial samples of fine wires are ascribable to variations in chemical quality or degree of purity of the metal.

In the course of these experiments it was brought to my notice by Lieut. Bucknill, R.E, that Mr. Farmer, of the United States, has recently devoted much attention to the improvement of appliances for the explosion of mines, and had applied German silver wire to the construction of low tension fuzes with very promising results; also that Commander J. Fisher, R.N., had entertained the idea of using an alloy of about 33 parts of platinum with 66 of silver, adopted by Matthiessen for the reproduction of the standard of electrical resistance. With the view of ascertaining whether wires of either of these alloys presented decided advantages over fine platinum wire, I obtained some from Messrs. Johnson and Matthey, which were submitted to experiments. The conclusions arrived at are as follows:—

1. Both the German silver and the platinum-silver alloy are greatly superior to platinum in regard to the resistance opposed to the passage of a current, and the heat consequently developed in giving lengths of wires of a particular diameter.

2. German silver is, in its turn, superior in this respect to the platinum-silver alloy, as is especially apparent in the finest wires. This superiority, though very marked in considerable lengths of wires of the same diameter, is, however, only trifling in short lengths; the comparatively ready fusibility of the platinum-silver wire contributes, with other physical peculiarities of the two alloys, to reduce the fine German silver wire to about a level with it, and sometimes even to a somewhat lower level, as regards the thermal effects produced. Some slight influence in this direction may perhaps also have been exerted in these particular experiments by the greater cooling power exerted, by the brass supports between which the wires were fixed, upon the German silver wire of comparatively low specific gravity.

In selecting a wire for the construction of low tension fuzes, its power to resist corrosion when in intimate contact with gunpowder or other substance employed as the igniting medium in such fuzes, especially if some moisture should be accidentally absorbed by them, possesses an important bearing upon its permanent efficiency. In Matthiessen's report on the application of platinum-silver wire to the preparation of standard resistance coils it is stated not to oxidise by exposure to air; it has, however, been observed to do so gradually, to the extent of becoming tarnished, and as, with extremely fine wires, a very superficial oxidation might appreciably affect the resistances of fuzes constructed with them, it was thought desirable to ascertain by actual experiment of a somewhat severe nature the power of such wires to resist corrosion in comparison with German silver wire. It was, of course, unnecessary to experiment with platinum wire in this direction. Wires of the two alloys, about 8 inches long, were enclosed in glass tubes, and each wire was surrounded closely by gunpowder and gun-cotton in the ordinary air-dry condition; one of each being also simply enclosed in air for purposes of comparison. In addition, a length of about 2 inches of each kind of wire was buried in wet gunpowder, the extremities being allowed to protrude sufficiently for testing purposes. Slight fluctuations were exhibited in two or three instances in the resistance-measurements of the fine and comparatively light German silver wire in the foregoing observations, and are no doubt ascribable to the effects of fluctuations of temperature, which did not influence the readings obtained with the platinum-silver wire, its conductivity being less affected by changes of temperature than that of any alloy experimented upon by Matthiessen. In all three experiments with the German silver wires enclosed in tubes there were indications of very slight superficial oxidation, as demonstrated by the permanent, though small, increase in the resistance of these wires, which, in the case of its exposure to contact with gun-cotton, continued very gradually up to the forty-first day, when it became stationary. The resistance of the platinum-silver wires in glass tubes remained constant throughout.

The exposure of the wires to contact with *wet* gunpowder has afforded very marked evidence of the greater liability of the German silver wire to corrosion; at the same time it must be borne in mind that this test far exceeds in severity any conditions under which fuzes constructed with wire bridges would be likely to be preserved in actual practice. It will be seen that the platinum-silver wire remained unaffected by this test for thirty-two days after the continuity of the German silver wire had been destroyed by corrosion. The great influence of the charcoal in the gunpowder in promoting corrosion in its capacity as an electrolyte is interestingly demonstrated by the fact that the German silver wire remained buried for twenty-two days in wet saltpetre without undergoing great oxidation (which oxidation did not progress after that time), while the wire which was buried in wet gunpowder was destroyed by corrosion within six days.

The foregoing comparative experiments appear to warrant the conclusion that a wire consisting of the alloy, composed of about 66 parts of silver and 33 of platinum, is not only superior to a platinum wire of considerably smaller diameter as regards the resistance it offers to the passage of an electric current, but that it is also, practically, quite equal in this respect to a German silver wire of the same diameter, and is at the same time greatly superior to the latter in its power to resist corrosion.

In selecting the platinum-silver alloy as the material for the reproduction of standards of electrical re-

sistance, Matthiessen referred (in his Report to the British Association Committee) to certain other advantages which it possesses, besides its low conducting power and its comparative freedom from liability to oxidation, namely, the slight extent to which its electrical resistance is altered by changes of temperature and its unalterability in this respect by exposure for several days to 100° C. These properties, though valuable with respect to its application as a trustworthy material for furnishing delicate measurements of electrical resistances, do not practically enhance its value as a material for the construction of fuzes. German silver ranks very little below it as regards the slight extent to which its conductivity is affected by changes of temperature (the increment in the resistance of the latter, due to elevation in temperature from 0° to 100°, being 4·4 per cent, and that of the platinum-silver alloy 3·2 per cent). The alloy which, among many experimented with by Matthiessen, was most affected in its conductivity by changes of temperature, sustained an increment of resistance of 28 per cent in passing from 0° to 100°; but the slight alteration in resistance which the short piece of wire (0·25" or 0·3") in a fuze made even with this alloy could sustain from extreme fluctuations of *atmospheric* temperature would be of no practical importance, being far exceeded by the accidental variations in the resistances of fuzes made with fine wire, which are unavoidable in their manufacture, as will be presently shown. The platinum-silver wires differ, however, in one respect very decisively from the other wires at present referred to as a means of electrical ignition, namely, in being much more readily fusible; and it appears not improbable that this peculiarity gives to wires of this alloy a decided advantage over those of platinum, and of an alloy of that metal to be presently mentioned, in their special application to the simultaneous explosion of a large number of fuzes, arranged in *divided* circuits of different lengths, in consequence of the certainty of an instantaneous interruption of each circuit by the fusion of the wire. A practical difficulty exists in the preparation of this particular platinum-silver alloy, arising out of a tendency to the separation of the metals (which are of widely different specific gravity) from each other to a very considerable extent, unless strict attention be paid to the temperature at which the alloy is cast, as well as to the cooling of the casting. It is therefore evident that special attention and experience are required to insure the production of an uniform platinum-silver alloy, with the high proportion of platinum essential to the preparation of a wire possessing the low conductivity which will enable it to compete with German silver.

It is hardly necessary to state that the metal *iridium*, which is associated in nature with platinum, and is, indeed, contained in very appreciable quantities in most specimens of even carefully purified platinum, is readily alloyed with it; and the fact that iridium reduces the conductivity of platinum very greatly was demonstrated by Matthiessen's experiments. An alloy of platinum with 33·4 per cent of iridium was found by him to have a conductivity of 4·54; that of the 33 per cent platinum-silver alloy being 6·7. These circumstances led me to make some experiments with wires of iridio-platinum, from which I conclude that that metal will prove as efficient in the production of sensitive fuzes as the finest platinum-silver; it possesses, moreover, the advantage of much greater strength, and it will certainly be more reliable than wire of that material as regards uniformity of composition. It is, however, much less fusible than the platinum-silver wire, as the fusibility of platinum is reduced by being alloyed with iridium; this may possibly give the platinum-silver wire an advantage in the case of "fork-firing," with a large number of branch circuits of different lengths (as in arrangements for the simultaneous discharge of a number of guns).* Wire fuzes of considerably higher resistance than any referred to in this paper may be produced by employing a wire containing a higher proportion of iridium than 10 per cent.

One other alloy has been specially recommended to me for experiment by Mr. Matthey, as being much more readily produced of uniform composition than the platinum-silver alloy, and as being a very readily workable material. Matthiessen experimented with an alloy of silver of 25 per cent of palladium, and found it to rank next above the platinum-silver alloy in conducting power. The alloy suggested for trial by Mr. Matthey contains 40 per cent of palladium and 60 per cent of silver. A fine piece 0·001" in diameter and 0·25" long of this wire offered a resistance of 1·7 ohms, which is about the same as that of the thicker of the two platinum-silver wires I experimented with. It is still more fusible than the latter, and ranks at least on an equality with it as regards power of resisting corrosion, so far as severe test-experiments have been carried up to the present time. There is little doubt, therefore, that this alloy of palladium is also a very efficient material for the construction of wire fuzes, offering considerable resistance.

In concluding these notes it may be useful to offer a few remarks relating to the construction of low tension or wire fuzes. It need hardly be stated that uniformity in resistance is an important quality to be aimed at; it is, moreover, a quality the attainment of which does not solely depend upon the employment a wire of uniform conductivity, but also demands careful attention to details in the construction of the wire bridge and in the application of the igniting material or "priming" round the bridge, the necessity for such care increasing with the fineness of the wire employed in the fuze.

Uniformity in the resistance of wire fuzes made with one particular kind and size of wire depends obviously in the first instance upon the employment of the same length of wire as the bridge in each fuze. With a view to attain this end the copper terminals must be accurately fixed at the same distance apart in the several fuzes; the wire must be always uniformly stretched across between these terminals (and therefore strained from one to the other as tightly as possible), and its two extremities must be attached to the terminals as uniformly as possible. The following general directions for constructing the terminals and wire-bridge will indicate the manner in which uniformity in the resistance of the fuzes may be attained.

The bared ends of the insulated copper wires which are to form the terminals are firmly fixed at a uniform distance apart (0·25 inch is found a very convenient distance) by being inserted into a die or mould, and partly embedded while in that position in a plug of some very hard cement or composition, which attaches itself thoroughly to the copper surfaces. A mixture of plaster of Paris or Portland cement and sulphur, which is cast round the wires while sufficiently hot to be viscid, is a good material for the purpose; or the wires may be imbedded in a plug of india-rubber preparation of the proper composition for subsequent conversion into ebonite. In either case the sulphur, which is a component of both preparations, attacks the surfaces of the copper wires, and thus insures their being quite immovable when the plug has cooled. The bare ends or terminals should project about 0·25 inch beyond the plug in which the wires have been fixed, and should be uniform in length and well brightened. In stretching the fine wire across from

* Some practical experiments, made since this paper was read, have demonstrated that an iridio-platinum wire of the smallest diameter, and containing about 10 per cent of iridium, is quite as efficient as the platinum-silver wire of corresponding diameter when applied in the above direction.

one terminal to the other pains should be taken to do this always as tightly as possible, and in a perfectly horizontal line, so as to insure the employment of uniform lengths of wire in different fuzes. Means should be adopted for making the terminals hold the wire by the obvious expedients of roughening the surfaces of the copper, or of cutting a fine slit into their extremities into which the wire may be inserted. The latter should, when properly strained and wrapped round, or let into the terminals, be firmly attached to these with solder, carefully applied by means of a small rod to *the back* of the terminals, so as not be brought into contact with the wire-bridge itself.

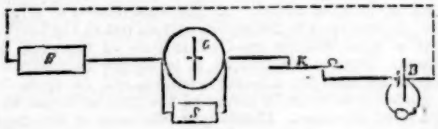
Either gun-cotton or gun-paper is now very generally employed as a *priming* agent in platinum wire fuzes, *i.e.*, as a means of facilitating the production of explosion by such fuzes, because the heat developed on passing a current through a fuze, if it should be insufficient to melt the wire, or to raise it to the temperature necessary for the ignition of gunpowder, may yet suffice to ignite the comparatively readily explosive gun-cotton. A small tuft of gun-cotton wool is generally pressed round the wire-bridge, or a piece of gun-cotton yarn is tied upon it; but, though either of these modes of applying the gun-cotton priming can be readily used in fuzes containing the comparatively coarse and strong wire hitherto employed, they are are not so easily applicable in conjunction with fine wires, as these are liable to be broken in the operation; or as, for fear of this occurring, the priming is not brought into properly close contact with the whole of the bridge, a condition which increases in importance as the source of heat in the fuze is diminished by a reduction of the thickness of the wire. A simple modification in the mode of applying the gun-cotton insures a thoroughly efficient priming of the fuze, without any risk of the fracture of the bridge being incurred. A very fine gun-cotton powder or dust is prepared by taking dry pulped gun-cotton, or compressed gun-cotton, scraped or broken up to powder, and sifting this through muslin; the dust thus obtained is intimately mixed by means of a feather or hair-pencil with sufficient mealed gunpowder or detonating powder to make it flow readily into a small cavity. When the bridge of the fuze has been fixed in position into the fuze-head or case, this priming powder may be poured in and made to surround the bridge thoroughly and compactly by a gentle tapping or shaking of the case without the slightest risk of breaking the bridge.

Correspondence.

METHOD OF ASCERTAINING RESISTANCE OF GALVANOMETER.

To the Editor of the Telegraphic Journal.

SIR,—The following neat method of ascertaining approximately the resistance of a galvanometer, when a second galvanometer is not at hand, may be useful to some of your readers and students generally:—



R is any resistance (say 100 ohms); G is the galvanometer (say a Thomson's mirror) whose resistance is to be measured; S a resistance-box; and B a single cell "shunted" with a short piece of wire, so as to obtain a convenient deflection on G. The combined resistance of the cell and its shunt is usually a small fraction of an ohm, and may therefore be disregarded.

Having arranged the apparatus as shown in the figure, first disconnect S, depress the key K, and note the deflection on G. Now halve R, making it 500 ohms, join up S, and vary its resistance until the original deflection on G is reproduced.

Then we have by the first arrangement—

$$\phi^{\circ} = \frac{E}{R + G} \quad . \quad . \quad . \quad . \quad (1)$$

And by the second arrangemement—

$$2\,\phi^{\circ} = \frac{E}{\frac{R}{2} + \frac{GS}{G+S}} \quad . \quad . \quad . \quad (2)$$

From which we obtain—

$$G = S \quad . \quad . \quad . \quad (3)$$

As the electromotive force of the cell will probably alter between the two operations, they should be performed as quickly as possible, and it would even be advisable to make two or three observations, and take the mean of them as the nearest approximation.

This method is somewhat similar to that described at p. 84 of "Clark and Sabine's Electrical Tables, &c.," but it is more accurate and (as will be seen by a comparison) far more simple.

J. J. FAHIE,
Assoc. Soc. Tel. Engineers

India, 25th July, 1874.

Electrical Science in English and Foreign Journals.

(In addition to our usual abstracts, there will be found under this heading the titles of papers on electrical science which have appeared in English and foreign journals from the commencement of the present century up to the date of the establishment of this journal).

Comptes Rendus Hebdomadaires des Séances de l'Academie des Sciences, Vol. lxxix., No. 6. August 10, 1874.

Fifth Note on the Conductibility of Ligneous Bodies.—By M. Th. Du Moncel.—Has already appeared in our columns as an original article communicated by the author.

Stratification of the Electric Light.—By M. Bidaud.—M. Neyreneuf's note which the author has only just read, induces him to say the following on the production of this phenomenon:—"In April last when repeating the experiment of the electric light in rarefied air, I replaced the tube, used to show the law of the fall of bodies in vacuum, by a straight Geissler tube with three swellings and 0·60 m. in length. One of the platinum wires communicated by a small chain with the earth, and the other was brought near the conductor of a Carré's machine. I then obtained a light as stratified in appearance as though the tube had been placed in communication with the secondary wire of Ruhmkorff's coil. Struck with this phenomenon, I perceived it only showed itself when the platinum wire was 1 to 4 c.m. distant from the conductor. Under these conditions a permanent purplish brush was given out, and the stratification was evident in all its beauty; it lost its distinctness when a spark had just been given out, and when the wire touched the conductor the glimmering was continuous. The charge of the conductor also influenced the conditions, but by trials the moment of maximum intensity was soon found. I compared this effect with that obtained from Ruhmkorff's coil, and the only difference was

that the production of very clear strata in the swelled parts of the tube which could be but diffusedly obtained with my Carré machine."

No. 7, August 17, 1874.

On the Use of the Aërial Helix as a Means of Measuring the Strengths of Voltaic Currents and the Mechanical Power of Electro-Magnetic Motors.—A note from M. W. de Fonvielle.—A small electro-magnetic motor constructed by M. Gaiffe was placed before the Academie des Sciences. Fitted with an "aërial helix" for a motor, set in motion by the action of a jar battery (pile-boutielle), it was found the motion accelerated according to the depth to which the zinc cylinder was plunged into the battery, and that the motion maintained a uniform movement when the zinc remained stationary. The speed of this uniform motion is a simple measure of the power of the electric current. With electro-magnetic motors of variable powers the rapidity of revolution is different, and the various motors being acted upon by the same battery we obtain a means of measuring their relative powers. M. Gaiffe intends to increase the usefulness of these instruments by adding indicators, so as to measure the speeds of revolutions.

No. 8, August 24, 1874.

Contains nothing suitable for our pages.

Bulletin de la Socite d'Encouragement. Vol. i., 3rd Series, No. 9. September, 1874.

On the Conductibility of Magnetic Tensions.—By M. Jamin.—A paper extracted from the *Comptes Rendus*, the matter of which has appeared in the "Electrical Science" columns of this Journal at various times.

The Journal of the Franklin Institute. Vol. xcviii., No. 582. June, 1874.

On a New and Constant Thermo-Electric Generator.—The direct production of electricity from heat, and its utilisation in practice as a source of power, has not, until now, been a commercial success. Unquestionably the best thermo-electric combination thus far obtained is that of Mr. Farmer, of Boston, in which an alloy of zinc and antimony constitutes the positive, and German silver or copper the negative plate. Such an electro-motor was exhibited at the Paris Exposition of 1867, and excited great interest. The difficulty, however, in their use on the large scale lies in the fact that when in action they lose their activity rapidly and "run down." Clamond has lately investigated the reason of this, and he finds it to be due to two causes: first, to the oxidation of the surfaces of contact of the two bars under the influence of the heat; and second, to the cracking of the crystalline bar and its breaking into transverse sections. While, therefore, the electromotive force of the apparatus undergoes no diminution, the internal resistance is so increased as to render the combination useless after a little time. The first of these difficulties Clamond has overcome by making some oblique cuts in the end of the flexible plate, and bending the intermediate tongues alternately to either side. When the melted metal is poured round this plate it flows into the spaces thus enclosed, and makes a more perfect contact. The second cause of deterioration was not so easily overcome. Annealing was found to be of no use, and it was finally ascertained that to render the bars homogeneous crystallisation must be prevented. This was effected by heating the moulds in which the zinc-antimony bars were cast to a temperature near that at which the alloy fuses, and by pouring in the metal at a temperature near its solidifying point. In this way, using the zinc-antimony alloy in connection with strips of iron, the author has succeeded in constructing a thermo-electric generator, which remained in action in the laboratory of M. Jamin, at the Sorbonne, for six entire months without deterioration. This apparatus consisted of three rings, each composed of ten pairs of bars, arranged radially. In the interior cylindrical space was placed an earthenware tube full of holes, serving as a gas-burner. The entire apparatus weighed about 14 lbs., and at an expense per hour of 6 cubic feet of gas, costing in Paris 1 cent, it deposited two-thirds of a troy ounce of copper; being equivalent to a Bunsen cell 7 inches high.

Duchemin's Circular Compass.—A new compass has been invented in France by M. Duchemin, the magnetic force of which resides, not in a bar or needle, as in the ordinary instrument, but in a flat steel ring, magnetised, with its poles at two opposite extremities of the same diameter. This ring, supported upon an aluminium traverse, pivoted on agate at its centre, has attached to it the ordinary compass card, and acts promptly and efficiently. The author claims for it the following advantages:—(1) a magnetic power, double that of a needle whose length is that of the diameter of the ring; (2) two neutral points instead of one, as in the needle; whence it happens that none of the magnetism escapes, and that strong sparks like those from the Holtz machine do not derange the poles; (3) a better and more prompt performance of the compass, the card seeming to float, as it were, in a liquid; (4) a large increase in the sensitiveness of the instrument; (5) the ability to regulate the magnetic intensity of the ring, and thus to compensate for local causes. This is effected by means of a second magnetised steel ring, smaller than, and inside of, the first, the position of which—and therefore its neutralising action—may be easily adjusted. Under the direction of the Minister of Marine a trial trip of the new compass was made on the steamboat *Faon* with very satisfactory results. M. Duchemin now proposes, as an improvement, the use of a set of such rings, forming a spherical or spheroidal system of still greater magnetic power.

Journal Telegraphique. No. 32. August 25, 1874.

Continuation of paper on *Telegraph Legislation: France.*

Iron Posts for the Military Telegraph: Lemasson's System.—This system was patented by M. Lemasson in France on April 28, 1874. Its chief feature is the capability of being rapidly set up, an all-important requirement for military telegraphy. The posts are each made in two or three sections, fitting into one another, thereby allowing them to be reduced to a half or a third their greatest height. The lowest section, in order to facilitate erection, is provided at its extremity with a steel point; the upper section is furnished with ebonite insulators, which screw on to the end of the posts. Steel fastening collars, or rings, fitted with screws to press and contract the collars, bind together the sections and permit the height to be regulated according the exigencies of the service. The advantages claimed are, that on a march the posts may be taken to pieces, and therefore more easily handled than is the case otherwise, especially when, as in steep and rugged roads, they have to be transported on the backs of mules. 2. The construction of a line on ground open to fire can be carried out at the height of a man without need of ladders or exposure of men. Once so constructed, it is simply necessary to raise by hand the different sections, and fix them to the lower sections by means of the steel collars at the desired elevation. Similarly in the case of breakage the broken portions can be easily lowered and repaired. Experiments on different grounds prove that by this system lines can be erected at the rate of 2 kilometres the hour, quick enough to follow the movements of a *corps d'armee.*

Nature, Vol. x., No. 247.

Vapourising Metals by Electricity.—A letter from A. Rodier.—In a paper, see TELEGRAPHIC JOURNAL, vol. ii., p. 270, Mr. Hopkins gave a short description of some experiments on vapourising metals by electricity between two microscopic slides, and said that the layer thus produced can be investigated by a microscope, and employed in various ways to determine the character of the metal. But the author did not point out the *wonderful figures* shown by the layer, chiefly when a slight gold sheet is used. This fact, very interesting in connection with molecular vibrations, has been illustrated by Prof. Magrini in a lecture delivered at the Museum of Florence some years ago, and translated in *La Revue Scientifique*, with some woodcuts prepared by Prof. Magrini himself.

Earth Shrinkings and Terrestrial Magnetism.—Substance of a letter from H. H. Howorth.—He believes that the earth is shrinking chiefly about its equatorial region, and is being thrust out in the direction of the poles, and that the distribution of this force may be correlated with that of terrestrial magnetism. Predicated, as to a great extent proved, that volcanoes are not found in areas of upheaval, but are indicative of areas of depression; also that the earth as a whole is shrinking. Volcanoes are most numerous in the equatorial regions, and constantly increase in numbers as we approach the equator from the poles. "It is a remarkable fact," says M. Reclus, "that the two volcanic groups of the Antilles and the Sunda Islands are situated exactly at the antipodes one of the other, and also in vicinity of the two poles of flattening, the existence of which on the surface of the globe has been proved by the recent calculations of astronomers." Mr. Howorth quotes from Dr. Zollner's paper in the *Philosophical Magazine* the subject of the correlation of earthquakes with magnetic disturbances, wherein it is stated that Kriel has given many cases where magnetic disturbances coincide with earthquakes; hence, he thinks, connection between the two phenomena probable. "These facts seem to me to support very strongly my contention that the earth is shrinking chiefly in its equatorial region; and volcanoes are in my opinion the mediate, and not the immediate, results of the shrinking of the earth; earthquakes, on the contrary, are its immediate results, and go far to prove that terrestrial magnetism is to be correlated with the force which is shrinking the earth."

No. 251.

The telegraphic apparatus at U.S. Naval Observatory at Washington is now connected with the main lines of the Western Union Telegraph Company, so that not only is the time-ball dropped daily at noon, but the same signal is widely distributed by the telegraph company. It goes directly from the observatory to the main office in New York City, and thence it is sent to nearly every State in the Union. The immediate object of these signals is to furnish accurate and uniform time to the railroads, and throughout the whole vast territory in question there is scarcely a train whose movements are not regulated by the observatory clocks. The clocks at the Navy Department, at the Army Signal Office, at the Treasury Department, and at the Western Union Telegraph Company's Offices are all constructed on the system known as Hamblett's, and are directly controlled by electric currents sent every second by the standard clock of the observatory.

Poggendorff's Annalen der Physik und Chemie.

VOL. L. (1840).

Continued Researches on the Induced Current of the Electric Battery. M. Riess. P. 1.

Miscellaneous Physical Experiments. M. Böttger. (Includes some in Electricity.) P. 35.

Electro-Chemical Experiment in Gold-plating of Silver and Brass. M. de la Rive. P. 94.

On Restoring the Strength of Weakened Magnets. M. Muncke. P. 221.

Improvements in the Magnet-Electrometer. M. Naumann. P. 236.

On the Thermo-Electricity of Crystals. M. Hankel. Pp. 237, 471, and 605.

New Thermo-Electric Battery. P. 250.

On the Exceptional Current Strength of the Zinc-Iron Couple; its Causes and some Related Subjects. M. Poggendorff. P. 255.

On the Influence of Heat on Electromotive Force of Galvanic Batteries. M. Poggendorff. P. 264.

Experiments on the Behaviour of Alternating Galvanic Piles. M. Pohl. P. 497.

On the Arrangement and Use of some Instruments for Measuring the Strength of Electric Currents, and the Elements conditioning them. M. Poggendorff. P. 504.

Comparative Measurement of the Action of a Copper-Zinc, and a Platinum-Zinc, Couple. M. Jacobi. P. 510.

Observations on the Smell given off in Electrolysation of Water, and the Flow of Electricity from Points. M. Schönbein. P. 616.

Note on Hollow Electro-Magnets as compared with Solid. M. Pfaff. P. 636.

VOL. LI. (1840).

On the Discovery of Electricity by Chemical Processes, and Experiments on the Electromotive Behaviour of many Liquids with Metals. M. Pfaff. Pp. 110, 177.

On an Observation with regard to Non-Conductors separating the Electric Charge. M. Knochenhauer. P. 112.

On the Maximum of Action of an Induction-Wire on the Discharge of the Electric Battery. M. Riess. P. 177.

On Electricity through Separation. M. Fechner. P. 321.

On the Direction of the Electric Induced Current. M. Riess. P. 351.

On the Principles of Electro-Magnetic Machines. M. Jacobi. P. 358.

Arrangements and Observations in the Domain of Galvanism. M. Mohr. P. 372.

On an Advantageous Construction of the Grove Battery. M. Gmël. P. 381.

On the Means of Giving the Current of a Galvanic Battery with One Liquid a Greater Strength. M. Poggendorff. P. 384.

VOL. LII. (1841).

Sixteenth Series of Experimental Researches on Electricity. Mr. Faraday. Pp. 149, 547.

Experiments on the Attractive and Repulsive Magnetic Force at Different Distances, and on its Relation to the Immediate Portative Force of Magnets. M. Cramer. P. 298.

On Strong Electro-Magnets, with Small and Large Horse-Shoe Pieces. M. Pfaff. P. 303.

A Thermo-Electric Observation. P. 314.

Note on the Electric Arithemometer. M. Riess. P. 315.

On the Electricity of Outflowing Steam. Mr. Armstrong. P. 328.

Unipolar Induction. M. Weber. P. 353.

Experimental Proof that an Electro-Dynamical Spiral Wire is yet no Magnet. P. 386.

On the Electric Decomposition of Water through Simple Zinc-Copper Couples. M. Henrici. P. 387.

On the Reality of Transition-Resistance in Hydro-Electric Currents. M. Poggendorff. P. 497.

City and Commercial Notes.

Under date of Sept. 4, Mr. Abbott says—There has been a distinct revival of business in telegraph securities during the past month, and the principal securities are steadily growing in favour with the investing public; prices have consequently improved, Anglo-American Stock taking the lead, the advance in this instance having exceeded 7 per cent.

The West India and Panama Company have at length got their system into such order that the "latest dates" show the time occupied between Demerara and London to be from forty-five minutes to three hours.

The traffics on the various submarine lines continue to be satisfactory; and it is understood that after the holidays the extension of the Globe Amalgamation will be carried out with vigour.

The traffic receipts of the Eastern Extension, Australasia, and China Telegraph Company, Limited, for the month of August, 1874, amounted to £19,697, against £19,219 for the corresponding period of 1873.

The Eastern Telegraph Company's traffic receipts for the month of August, 1874, amounted to £31,265, against £28,091 in the corresponding period of 1873.

The number of messages passing over the Cuba Submarine Telegraph Company's line during the month of August amounted to 1725, estimated to produce £2000, against 1260 messages, producing £1216, in August last year.

The traffic receipts of the Great Northern Telegraph Company for the month of August were—this year, 414,553 francs; last year, 331,238 francs. The total traffic receipts from 1st January to 31st August were—this year, 2,914,362 francs; last year, 2,053,350 francs.

The receipts of the Submarine Telegraph Company for the month of August, 1874, amounted to £8853 8s. 1d.; those for the corresponding month of the preceding year were £8439 0s. 6d.

The Great Northern Telegraph Company has obtained a concession from the Chinese Government for the establishment of a land line from Amoy to Foochow; and as the erection of the line has already been commenced, the important port of Foochow will soon be in telegraphic communication with Europe.

McLean's Telegraphic Bureau, which for many years past has been engaged in the transmission of cable despatches of one word and upwards to the United States and Canada, announces a large reduction in cable rates. Tariffs can be had on application at 39, Lombard Street.

TELEGRAPH SHARE LIST.

Amount per Share.	Name of Company.	Amount paid up.	Closing Quotations.
£		£	Sept. 14.
Stock	Anglo-American (Limited)	100	77½–78½
10	Brazilian Submarine	All	7¼–7½
10	Cuba	All	5¼–6½
10	Direct Spanish	9	..–..
20	Direct United States Cable	All	13–14
10	Eastern (Limited)	All	8⅞–8⅞
..	Do., New	..	104–106
10	Eastern Extn. Australia and China	All	8–8¼
10	Globe Telegraph and Trust	All	6⅝–7⅛
10	Do., 6 per cent Pref.	All	9⅜–10⅛
10	Great Northern	All	11–11¼
25	Mediterranean Extension (Limited)	All	16–17
10	Do., 8 per cent Pref.	All	4–4¼
10	Panama and South Pacific	All	10½–11⅜
10	Reuter's	2½	..–..dis
8	Submarine	All	11–11½
Stock	Do., Scrip	100	205–215
1	West India and Panama	All	2–2½
10	Do., 10 per cent Pref.	All	4–4½
10	Western and Brazilian (Limited)	All	10¼–10⅜
20	West Un. U.S. 7 per cent 1st M.B.	All	10⅜–10⅝
1000 dls.	Hooper's Telegraph Works	All	12–12½
50	India-Rubber and Gutta Percha	All	24–27
(Perl.	Submarine Cables Trust	100	107–110
15	Telegraph Construction	All	26–29
100	Ditto Ditto 7 per cent Bonds	All	103–105

The number of messages (of twenty words) passing over the Barcelona-Marseilles cable for the month ending August 31, 1874, was 6138.

In Japan the Company's repairing steamer is at present submerging cables for account of the Japanese Government for the purpose of connecting Nippon and Yesso.

Patents.

Notices to Proceed.

2478. W. H. Davies and F. H. W. Higgins, both of 17 and 18, Cornhill, London, have given notice in respect of the invention of "Improvements in telegraphic signalling instruments for transmitting a number of fire and other alarms or calls upon a single wire."—*Dated July* 15, 1874.

Grants for Provisional Protection for Six Months.

2625. T. Slater, of Euston Road, London, electrician, for the invention of "Improvements in electro-magnets, and in batteries or apparatus to be employed therewith."—*Dated July* 27, 1874.

2628. T. Welton, of Grafton Street, Fitzroy Square, Middlesex, for the invention of "Improved means or apparatus for generating and applying electricity for therapeutic purposes."—*Dated July* 29, 1874.

2637. G. K. Winter, F.R.A.S., Telegraph Engineer of the Madras Railway, Arconum, Madras, for the invention of "Improvements in electrical inter-communication in trains."—*Dated July* 29, 1874.

2648. A. M. Clark, of 53, Chancery Lane, Middlesex, patent agent, for the invention of "Improvements in electro-magnetic governors for steam heating and drying apparatus."—A communication to him from abroad by J. M. Bradford, of Portland, Cumberland, Maine, U.S.A.—*Dated July* 29, 1874.

Birkbeck Literary and Scientific Institution.—Mr. W. J. Wilson, F.C.S., F.P.S., Demonstrator of Practical Physics at the Royal School of Mines and Science Schools, South Kensington, will deliver thirty Lectures on Electricity and Magnetism, on Friday evenings, at Eight o'clock, commencing October 2nd. These Lectures are especially designed to prepare Students for the Evening Examinations of the Science and Art Department, with which the Courses will terminate in May. At the Class Examinations of the Science and Art Department, May, 1874, 130 papers in Physics were worked by Mr. Wilson's pupils. Of these a Studentship in Physics, at South Kensington, has just been awarded to one of the above Students; 87 passed First Class and obtained Queen's Prizes, 41 passed Second Class, and two failed. In May, 1873, 68 papers were worked; 45 passed First Class, 23 Second Class, and *none failed*.

To Correspondents.

*** **Duly authenticated contributions, theoretical and practical, on every subject identified with the interests of which "The Telegraphic Journal" is the organ, will always command attention. Anonymous correspondence will be wholly disregarded. Literary communications and books for review should be addressed to the Editor; business communications to the Publisher.**

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Copies of the journal may be obtained through newspaper agents in every part of the world. Should any difficulty arise in procuring copies, direct communication with the Publisher is requested.

Cheques and Post Office Orders to be made payable to Henry Gillman, and to be crossed "London and County Bank."

ALL SUBSCRIPTIONS PAYABLE IN ADVANCE.

L. V. Fraser (British Burmah).—Your letter and enclosure came safely to hand.

G. K. Winter and H. D. A. Ward.—Received with thanks.